LONG-TERM MONITORING OF PUGET SOUND, GRAYS HARBOR AND WILLAPA BAY: STATUS AND TRENDS IN WATER QUALITY FROM 2001-2005

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Conclusions

- 5-year trends at 40 long-term monitoring stations have been evaluated.
- Indices of water quality and eutrophication have been developed.
- Areas showing the highest sensitivity to eutrophication have very low DO, low DIN, and strong and persistent stratification.
- Areas showing the highest sensitivity to eutrophication are Saratoga Passage, Possession Sound, Penn Cove and Hood Canal.
- Areas with poorest water quality include Possession Sound, Penn Cove, Budd Inlet, Hood Canal, and Grays Harbor.
- Indices of Eutrophication and Water Quality Concern show that areas with poor water quality are increasing, indicating the continued degradation of Puget Sound waters.

Introduction

The Washington State Department of Ecology has been monitoring the water quality of Washington's estuaries for 35 years, more recently as part of the Puget Sound Assessment and Monitoring Program (PSAMP). This monitoring effort is designed to assess the status of these waters and to detect long-term changes using a range of physical, biological, and chemical parameters in marine waters at 40 long-term stations (Figure 1).

Water quality is one of the primary factors affecting the health of the Puget Sound region. Increases in development around Puget Sound have prompted many investigations into the sources, loadings, pathways, and effects of nutrient pollution. Nutrient availability involves inputs from various natural and human sources and monitoring of these inputs is critical for assessing and understanding both short- and long-term changes in water quality in Puget Sound. Eutrophication (nutrient-driven changes in marine ecosystems) is one of the most important issues in coastal ecosystems worldwide, including Puget Sound.

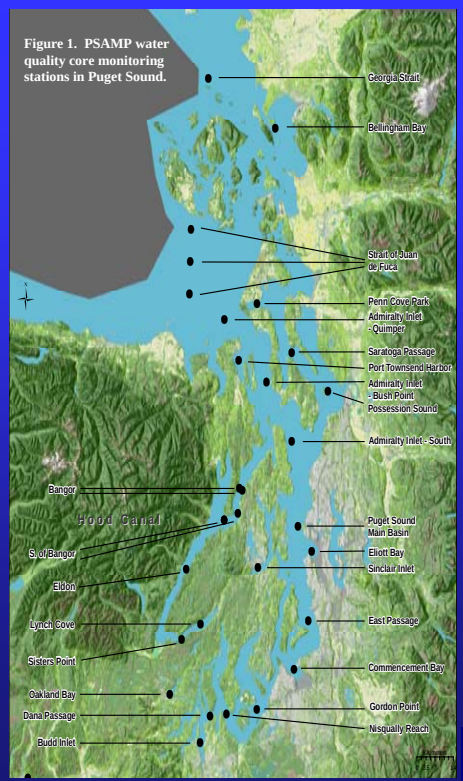

Figure 1. PSAMP water quality core monitoring stations in Puget Sound.

Lynn Schneider lowering the CTD from the seaplane.

Figure 2. PSAMP marine water quality monitoring stations in Grays Harbor and Willapa Bay.

Sensitivity to Eutrophication Index

The potential for eutrophication in Puget Sound depends on a variety of factors, including:

1. Concentrations of dissolved inorganic nitrogen (DIN)
   - Low levels indicate that phytoplankton growth may be nutrient-limited and therefore, additional nitrogen would lead to increasing eutrophication.
2. Dissolved Oxygen concentration
   - Low DO is often associated with a combination of strong stratification and high productivity driven by high nutrient availability.
3. Persistence of stratification
   - Strong and persistent stratification indicates that mixing of surface and bottom waters is reduced both spatially and temporally, leading to oxygen depletion.

Using data from 2001-2005 for three indicators, sensitivity to eutrophication was assessed for each monitoring station. Stations were assigned to one of four risk categories based on their numerical scores for each indicator. In a few instances, stations were placed in higher or lower categories based on special considerations such as basin morphology and bathymetry, circulation and retention times (see Table 1).

Areas of Very High risk include:
- Hood Canal (especially southern Hood Canal)
- Penn Cove
- Saratoga Passage (formerly high risk)
- Possession Sound

Areas of High risk include:
- Budd Inlet
- Bellingham Bay
- Nisqually Reach
- Carr Inlet
- Henderson Inlet

Areas of Low risk include:
- Grays Harbor
- Willapa Bay

Table 1. Indicator results and Sensitivity to Eutrophication Index for Puget Sound marine monitoring stations 2001-2005. Stratification rankings are Strong and Persistent (SP), Strong and Intermittent (SI), Moderate and Intermittent (M Int), Moderate and Infrequent (MI), and Weak and Infrequent (WI).

Location	DO	DIN	Stratification	Sensitivity to Eutrophication
Saratoga Passage	Very Low	Low	SP	Very High
Possession Sound	Very Low	Low	SP	Very High
Penn Cove	Very Low	Low	SP	Very High
Hood Canal - Sisters Pt.	Very Low	Low	SP	Very High
Bellingham Bay - Pt. Frances	Very Low	Mod	SI	High
Budd Inlet - South Port	Very Low	High	SI	High
Budd Inlet - Olympia Shoal	Very Low	Mod	MI	High
Admiralty Inlet South	Very Low	High	SI	High
Port Gardner West	Low	High	SP	High
Nisqually Reach	Very Low	High	WI	High
[1]Hood Canal - Bangor	Low	High	M Int	High
[2]Sinclair Inlet	Low	Mod	MI	High
[2]Carr Inlet	Low	Mod	WI	High
[2]Henderson Inlet	Low	High	WI	High
Willapa Bay - S. Jenson Pt.	High	Low	WI	Moderate
Willapa Bay - Nahcotta Channel	High	Low	MI	Moderate
Strait of Georgia	Low	High	SI	Moderate
Quartermaster Harbor	Low	Mod	MI	Moderate
Port Gamble	Low	Mod	MI	Moderate
Point Jefferson	Low	High	SI	Moderate
Elliott Bay	Low	High	SI	Moderate
Elliot Bay	Low	High	SI	Moderate
Commencement Bay - Browns Pt.	Low	High	SI	Moderate
Commencement Bay	Low	High	SI	Moderate
Bellingham Bay - Nooksack	Low	High	SI	Moderate
Willapa River - Raymond	High	High	SI	Moderate
Willapa River - John. Slough	High	High	SI	Moderate
Port Townsend	Low	High	MI	Moderate
Port Orchard	High	Mod	WI	Moderate
Port Angeles Harbor	Low	High	WI	Moderate
Oakland Bay	High	Mod	MI	Moderate
East Sound	Low	High	MI	Moderate
Drayton Harbor	High	Mod	M Int	Moderate
Dana Passage	Low	High	WI	Moderate
[4]Willapa Bay - Toke Point	High	Mod	MI	Low
[4]Willapa Bay - Naselle River	High	Mod	MI	Low
[3]Grays Harbor - Chehalis River	High	High	SP	low
[3]Grays Harbor - Damon Pt.	Low	High	MI	Low
[4]West Point	Low	High	MI	Low
[4]East Passage	Low	High	MI	Low
[4]Admiralty Inlet - Quimper Pn.	Low	High	MI	Low
[4]Admiralty Inlet - Bush Pt.	Low	High	MI	Low
Totten Inlet	High	High	MI	Low
Point Wells	High	High	MI	Low
Grays Harbor - South Channel	High	High	MI	Low
Gordon Point	High	High	WI	Low
Dolphin Point	High	High	MI	Low

[1]Station has moved due to Navy security restrictions. Alternate sampling sites are located in areas with different physical characteristics, which may impact water quality observations. Station believed to be higher-risk based on historical observations.

[2]Station located in enclosed or semi-enclosed water body; increased risk due to reduced circulation.

[3]Station located in shallow, well-flushed areas; reduced risk.

[4]Station located in well-mixed, well-flushed passage or basin; reduced risk.

Water Quality Concern Index

Ecology uses five indicators to calculate an index of water quality concern:

1. Fecal coliform bacteria levels
   - High levels indicate the presence of a nearby contaminant source.
2. Concentrations of dissolved inorganic nitrogen (DIN)
   - Low levels indicate that phytoplankton growth may be nutrient-limited and, therefore, the water body may be sensitive to the effects of eutrophication.
3. Ammonium (NH4) levels
   - High concentrations indicate the presence of a nutrient source.
4. Dissolved Oxygen concentration
   - Low DO is often associated with a combination of strong stratification and high productivity driven by high nutrient availability.
5. Persistence of stratification
   - Strong and persistent stratification indicates that mixing of surface and bottom waters is reduced both spatially and temporally.

Areas of Highest concern:	Minimum DO measured (mg/l)
Hood canal (especially southern hood canal)	0.31 - Sept. '04
Penn cove	0.99 - Apr. '03
Budd inlet	1.61 - Mar. '03
Saratoga Passage (added for 2001-2005)	2.75 - Nov. '05
Possession Sound (added for 2001-2005)	2.85 - Sept. '02

Areas of High concern include:	
Commencement Bay	3.76 - Oct. '02
Elliott Bay	4.04 - Dec. '01
Bellingham Bay	2.27 - Oct. '02

See Table 2 for a complete list of water quality indices.

Table 2. Indicator results and Water Quality Index for Puget Sound marine monitoring stations, based on 2001-2005 data.

Location	DO	FCB	DIN	NH4	Stratification	WQ Concern
Possession Sound	Very Low	High	Low	Low	SP	Very High
Penn Cove	Very Low	Low	Low	Mod	SP	Very High
Budd Inlet - South Port	Very Low	High	High	High	SI	Very High
Saratoga Passage	Very Low	Low	Low	Low	SP	Very High
Hood Canal - Sisters Pt.	Very Low	Low	Low	Low	SP	Very High
Budd Inlet - Olympia Shoal	Very Low	High	Mod	Mod	MI	Very High
Grays Harbor - Chehalis River	High	High	High	Mod	SP	Very High
Bellingham Bay - Pt. Frances	Very Low	Mod	Mod	Mod	SI	High
Commencement Bay	Low	High	High	Mod	SI	High
Willapa River - Raymond	High	High	High	Mod	SI	High
Willapa River - John. Slough	High	High	High	Mod	SI	High
Quartermaster Harbor	Low	Low	Mod	High	MI	High
Oakland Bay	High	High	Mod	Mod	MI	High
Elliott Bay	Low	High	High	Low	SI	High
Elliot Bay	Low	High	High	Low	SI	High
Commencement Bay - Browns Pt.	Low	High	High	Low	SI	High
Admiralty Inlet South	Very Low	Mod	High	Low	SI	High
Willapa Bay - S. Jenson Pt.	High	Low	Low	Mod	WI	High
Willapa Bay - Nahcotta Channel	High	Low	Low	Mod	MI	High
West Point	Low	High	High	Low	MI	High
Port Gardner West	Low	Low	High	Low	SP	High
Port Angeles Harbor	Low	High	High	Low	WI	High
Nisqually Reach	Very Low	Low	High	Mod	WI	High
Grays Harbor - South Channel	High	High	High	Mod	MI	High
East Sound	Low	Low	High	High	MI	High
Sinclair Inlet	Low	Mod	Mod	Mod	MI	Moderate
Willapa Bay - Naselle River	High	Mod	Mod	Mod	MI	Moderate
Point Jefferson	Low	Mod	High	Low	SI	Moderate
Carr Inlet	Low	Low	Mod	Mod	WI	Moderate
Bellingham Bay - Nooksack	Low	Low	High	Mod	SI	Moderate
Willapa Bay - Toke Point	High	Mod	Mod	Low	MI	Moderate
Strait of Georgia	Low	Low	High	Low	SI	Moderate
Port Gamble	Low	Low	Mod	Low	MI	Moderate
Hood Canal - Bangor	Low	Low	High	Mod	M Int	Moderate
Drayton Harbor	High	Low	Mod	Mod	M Int	Moderate
Totten Inlet	High	Low	High	Mod	MI	Low
Port Townsend	Low	Low	High	Low	MI	Low
Port Orchard	High	Low	Mod	Low	WI	Low
Point Wells	High	Low	High	Mod	MI	Low
Henderson Inlet	Low	Low	High	Low	WI	Low
Grays Harbor - Damon Pt.	Low	Low	High	Low	MI	Low
East Passage	Low	Low	High	Low	MI	Low
East Passage	Low	Low	High	Low	MI	Low
Dana Passage	Low	Low	High	Low	WI	Low
Admiralty Inlet - Quimper Pn.	Low	Low	High	Low	MI	Low
Admiralty Inlet - Bush Pt.	Low	Low	High	Low	MI	Low
Gordon Point	High	Low	High	Low	WI	Low
Dolphin Point	High	Low	High	Low	MI	Low

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